DIEL FLUCTUATIONS IN CATCH OF POSTLARVAL WHITE SHRIMP, *PENAEUS SETIFERUS* (LINNAEUS), WITH THE RENFRO BEAM TRAWL[1]

CHARLES W. CAILLOUET, Jr.
Institute of Marine Sciences, University of Miami

BENNIE J. FONTENOT, Jr.
Louisiana Wild Life and Fisheries Commission,
New Orleans, Louisiana 70130

AND

RONALD J. DUGAS
Department of Biology, University of Southwestern Louisiana,
Lafayette, Louisiana 70501

Abstract

From August 30 through September 3, 1964, duplicate (clockwise and counterclockwise) semicircular tows of 100-ft radius were made with the Renfro beam trawl every 2 hours over a 98-hour period. The sampling site was a tidal flat adjacent to the shoreline at Cheniere la Croix, Louisiana, bordering the Gulf of Mexico. A total of 9,462 postlarval white shrimp, *Penaeus setiferus* (Linnaeus), were captured. Because the standard deviation of catches (numbers of postlarvae) taken in duplicate tows was proportional to the arithmetic mean of duplicate catches, the geometric mean catch per tow was used as a measure of relative abundance of postlarvae. Peak catches of postlarvae per tow occurred at night, 2-4 hours after high water and at the lowest water temperature, during each of the four 24-hour periods. Minor peak catches occurred each afternoon near the low-water stage and at the highest water temperature during each 24-hour period.

Introduction

A small beam trawl designed by Renfro (1963) has been used to measure relative abundance of postlarval shrimp (*Penaeus* spp.) in the shallow waters near the shoreline of estuaries bordering the Gulf of Mexico (Baxter, 1963; Baxter & Renfro, 1966; Christmas, Gunter & Musgrave, 1966). Several factors have been shown to influence the catch of postlarvae with the beam trawl, which is usually towed in a semicircle of constant radius adjacent to the shoreline. Disturbance of the substrate by both the person towing the net and the metal pipe beam that drags in front of the mouth of the net presumably causes postlarvae on the bottom to rise into the path of the net's mouth. Caillouet, Dugas & Fontenot (1968) showed that tows of 50-ft radius were no less efficient than tows of 100- and 150-ft radius in capturing postlarvae. Baxter (1964) reported diel variation in catch of postlarvae with the beam trawl. Using different gear, other investigators have also demonstrated diel fluctuations in catch

[1]Contribution No. 962 from the Institute of Marine Sciences, University of Miami.

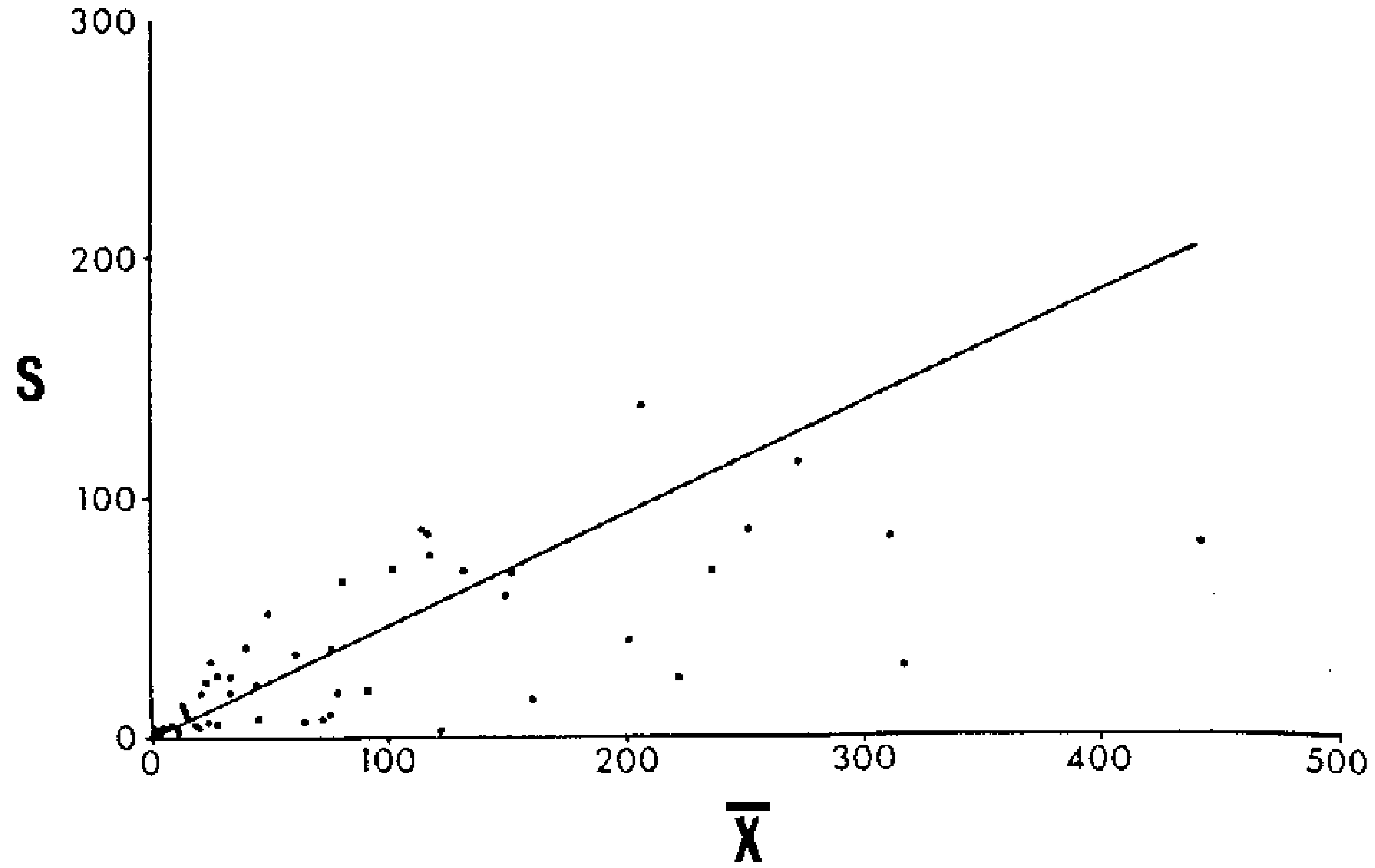

FIGURE 1. Relationship between the standard deviation (s) and arithmetic mean ($\bar{x}$) of duplicate catches of postlarval white shrimp. Line fitted according to regression model 1A (Snedecor, 1956: 153): $\hat{s} = 0.47\ \bar{x}$.

of postlarval shrimp (Hughes, 1967; St. Amant, Broom & Ford, 1966; Tabb, Dubrow & Jones, 1962).

The purpose of this investigation was to measure diel fluctuations in catch of postlarval white shrimp, *Penaeus setiferus* (Linnaeus), with the Renfro beam trawl.

METHODS

From August 30 through September 3, 1964, duplicate (clockwise and counterclockwise) semicircular tows of 100-ft radius were made with the Renfro beam trawl every 2 hours over a 98-hour period. The sampling site was a tidal flat adjacent to the shoreline at Cheniere la Croix (T 17 S, R 4 E, Section 24) on the south side of Marsh Island, Louisiana, bordering the Gulf of Mexico. The substrate was finely ground shell and firm, heavy mud. The first of each pair of tows was made in a counterclockwise direction and the second in a clockwise direction. Water temperature and tidal elevation were recorded each time duplicate tows were made.

Samples were fixed in a solution of 10-15 per cent formalin and 5 per cent glycerin, buffered with sodium tetraborate decahydrate. Postlarvae were later removed and counted. Subsamples of not more than 25 postlarvae from every sample were identified to species according to Pearson (1939) and Williams (1959). The sampling was conducted in the fall to decrease the likelihood of capturing *Penaeus* spp. other than white shrimp.

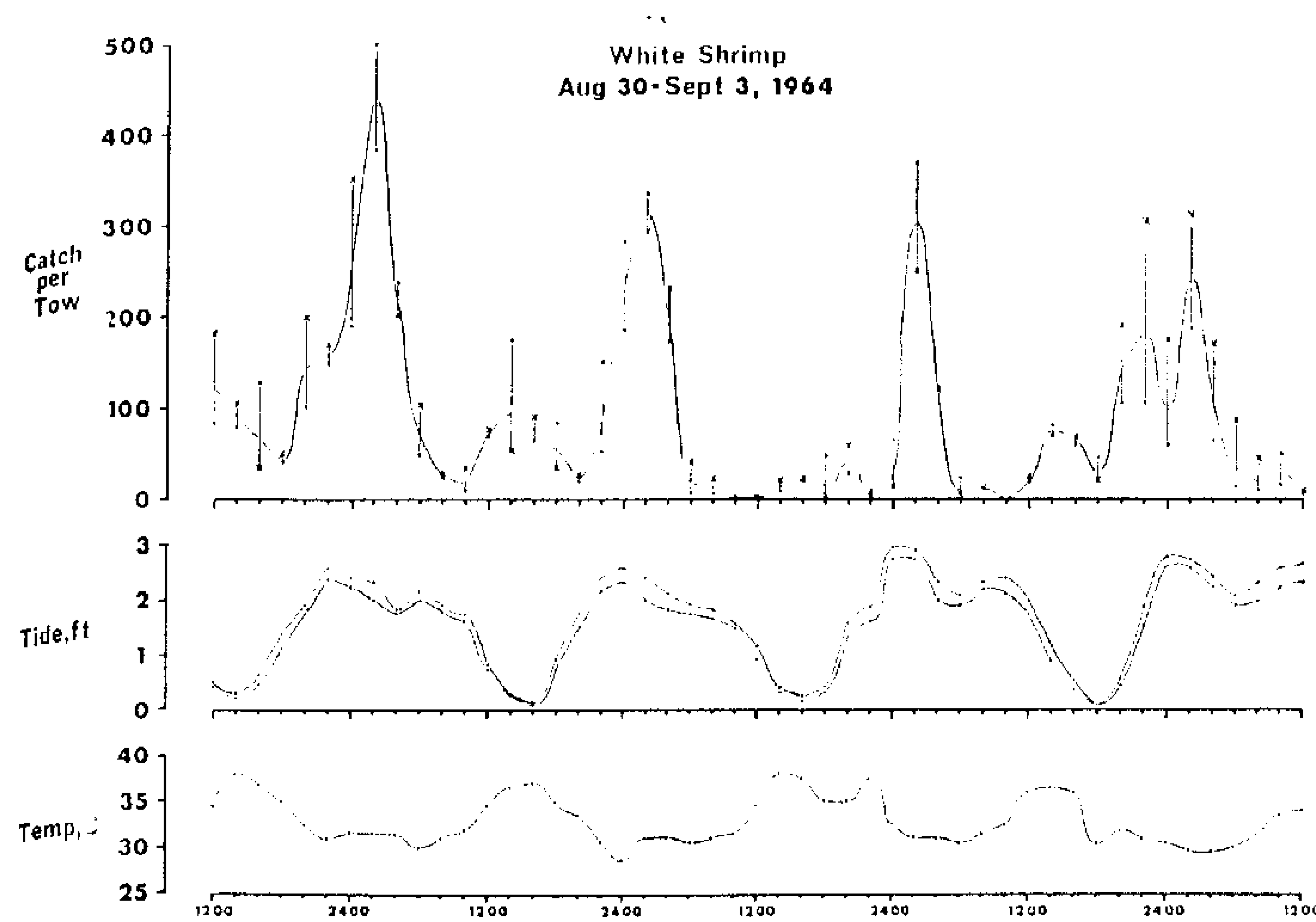

FIGURE 2. Fluctuations in catch, tide, and temperature of water during a 98-hour period at Cheniere la Croix, Louisiana, August 30 through September 3, 1964: Top, catch of postlarval white shrimp per tow. (Vertical lines represent the ranges in duplicate catches: x's represent the catches in counterclockwise tows; dots represent the catches in clockwise tows; the continuous line through the points indicates the geometric means of duplicate catches.) Middle, the tides. (Wave height is represented by the vertical distance between points.) Bottom, the water temperatures.

RESULTS

Of the 9,462 postlarvae captured during the study, the 1,959 identified to species were all white shrimp. The standard deviation of catches (numbers of postlarvae) taken in duplicate tows was proportional to the arithmetic mean of duplicate catches (Fig. 1), i.e., the coefficient of variation of duplicate catches was relatively constant. Therefore, the geometric mean catch per tow (square root of the product of catches in duplicate tows) was used as a measure of relative abundance of postlarvae (Fig. 2) and a logarithmetic transformation of catches was performed to assure additivity and homogeneity of variance prior to analysis of variance. Since no postlarvae were taken in some tows, 1 was added to each catch before it was transformed to a common logarithm. The following analysis of variance of the transformed data detected significant ($P < 0.05$) differences in catch per tow among the four days (from hours 1200 to 1000) of sampling and among hours of the day:

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Sampling periods	47	30.6931	0.6530	9.40*
Days	(3)	(7.3260)	2.4420	35.14*
Hours	(11)	(17.5061)	1.5915	22.90*
Interaction	(33)	(5.8610)	0.1776	2.56*
Duplicate tows	48	3.3357	0.0695	
Total	95	34.0288		

* Significant at $P < 0.05$.

There was also a significant interaction between days and hours, but the contribution of this interaction to the variation in catch of postlarvae was not as great as that of either days or hours alone.

Peak catches of postlarvae were taken at night (between and including the hours of 2000 and 0400) 2-4 hours after the high-water tidal stage in each of the four tidal cycles (Fig. 2). Minor peak catches occurred each afternoon near the low-water stage. The peaks in catch at night occurred when the water temperature was lowest, but the minor peaks that were observed during the day occurred when the water temperature was highest. On such a tidal flat, water temperature can be expected to increase when low water occurs during the day and results in exposure of shallow areas to the heat of the sun, and it can be expected to decrease at night with incoming tidal currents. There was a relatively strong negative correlation ($r = -0.67$) between tide and water temperature.

Discussion

Peak catches of postlarval white shrimp occurred at night, 2-4 hours after high water, and at the lowest water temperature during each of the tidal cycles in this study. Tabb, Dubrow & Jones (1962), using a plankton net operated from a stationary position in a tidal canal, reported that catches of postlarval pink shrimp, *Penaeus duorarum*, were greater at night than during the day and were greater during flood tide than during ebb tide. Catches of postlarval shrimp (probably brown shrimp, *Penaeus aztecus*) were observed by Baxter (1964) to be higher at night (from 2000 to 0600 hours) than during the day. St. Amant, Broom & Ford (1966) showed that catches of postlarval shrimp (probably both white and brown shrimp) were greatest in periods of incoming tide, but they detected no relationship between catch and time of day. Though results of these studies are similar, they are not all directly comparable because of differences in gear and method of operation of gear. Both our study

and that of Baxter (1964) employed the Renfro beam trawl, an active gear. The passive gears used by Tabb, Dubrow & Jones (1962) and St. Amant, Broom & Ford (1966) depended upon water movement for their operation; nevertheless, movement of postlarvae was shown to occur unidirectionally with the flood tide or incoming tidal currents.

Hughes (in press) concluded that tide-associated movements of postlarval pink shrimp were related to the changes in salinity that normally occur in the tidal cycle, but these movements seemed to be conditioned by rhythmic control. The postlarvae rose from the substrate and were more active at the higher salinities associated with periods of incoming tidal currents. They settled to the bottom and became inactive at the lower salinities that usually accompany outgoing tidal currents. Since the postlarvae were not capable of swimming against strong currents, they were passively displaced when off the substrate and active in the water of higher salinity associated with incoming tidal currents.

It was possible that catch of postlarval white shrimp with the Renfro beam trawl was influenced in part by changes in volume of water strained through the net. At least two conditions associated with the tidal cycle could have contributed to these changes: (1) changes in direction and velocity of currents near the shoreline, and (2) changes in configuration of the gear. When current direction deviates from a direction perpendicular to the shoreline, more water should be strained through the net when towed in one direction (into the current) than in the opposite direction (with the current). It is reasonable to expect such deviation in current direction with flood and ebb tides. Changes in velocity of tidal currents are also associated with flood and ebb tides. At low water, the gear was towed in water not more than about 1 ft deep. Both the metal beam and the entire lead-weighted footline chafed the bottom, and the whole floatline was at the surface, giving the mouth of the net a flattened oval shape. At high water, the gear was buoyed to a greater extent, there was not as much chafing of the bottom, and the mouth of the net was held wide open by floatline and leadline. Apparently, more water was strained through the net during flood and ebb tides when current velocity was greatest, yet peak catches were not made at these times but occurred 2-4 hours after high water when current velocity was low. Minor peak catches also occurred with low current velocity accompanying low water.

It appears that the postlarval white shrimp were carried shoreward at night by the incoming tidal currents and reached peak abundance 2-4 hours after high water. The rapid decline in abundance thereafter could have resulted from emigration of postlarvae from the sampling area, or decreased vulnerability of postlarvae to the gear, or both. It seems likely that the postlarvae would be more vulnerable to the gear when actively swimming than when settled on the bottom. If the postlarvae were on the bottom and not active during the day, disturbance of the bottom by the persons towing the gear in shallow water and by the gear itself might have contributed to minor peak catches that occurred each afternoon at low water. The relatively high water temperature at that time may have induced the postlarvae to become more active as well. However, these minor peaks in catch may have been produced by immigration of postlarvae into the sampling area with the outgoing tidal currents.

Acknowledgments

This study was supported by contract 14-17-0002-100 from the Bureau of Commercial Fisheries, Fish and Wildlife Service, U. S. Department of the Interior. Facilities and equipment were also provided by the Department of Biology, University of Southwestern Louisiana, Lafayette, Louisiana. We are grateful to Mr. Milton J. Lindner and Mr. Richard J. Berry of the Biological Laboratory, Bureau of Commercial Fisheries, Galveston, Texas, for critical review of the manuscript. The assistance of Mr. David M. Soileau, Mr. Houston F. Herbert, Miss Shelley M. Nix, Mr. William S. Perret, and Mr. Allen R. Comeaux was greatly appreciated.

Sumario

Fluctuaciones Diarias en la Captura de Postlarvas del Camaron Blanco, *Penaeus setiferus* (Linnaeus), con la Red de Viga de Renfro

De agosto 30 a septiembre 3 de 1964, redadas semicirculares de 100 pies de radio, dobles—a favor y en contra del movimiento de las manecillas del reloj—fueron hechas con la red de viga de Renfro, cada 2 horas, por un período de más de 98 horas. El lugar de muestreo fue un bajo expuesto por la marea, próximo a la línea de la costa en Cheniere la Croix, Louisiana, bordeando el Golfo de México. Se capturó un total de 9,462 postlarvas del camarón blanco, *Penaeus setiferus* (Linnaeus). Debido a que la desviación regular de las capturas (número de postlarvas), tomadas en redadas dobles, fue proporcional a la media aritmética de las capturas dobles, la media geométrica de captura por redada fue usada como una medida de la relativa abundancia de postlarvas. Los puntos de máxima en la captura de postlarvas por redada tuvieron lugar en la noche, de 2-4 horas después de la marea alta, y a la más baja temperatura del agua, durante cada uno de los cuatro períodos de 24 horas. Los puntos de mínima captura tuvieron lugar cada tarde, cerca de la marea baja y a la más alta temperatura del agua durante cada período de 24 horas.

Literature Cited

Baxter, K. N.
1963. Abundance of postlarval shrimp—one index of future shrimping success. Proc. Gulf & Carib. Fish. Inst., 15th Ann. Sess., 79-87.

1964. Abundance of postlarval and juvenile shrimp. Circ. U. S. Bur. Comm. Fish., No. 183: 28-29.

Baxter, K. N. and W. C. Renfro
1966. Seasonal occurrence and size distribution of postlarval brown and white shrimp near Galveston, Texas, with notes on species identification. Fishery Bull. U. S. Bur. Comm. Fish., *66:* 149-158.

Caillouet, C. W., Jr., R. J. Dugas, and B. J. Fontenot, Jr.
1968. Effects of radius and direction of semicircular tow near the shoreline on catch of postlarval shrimp (*Penaeus* spp.) with the Renfro beam trawl. Trans. Amer. Fish. Soc., *97:* 127-130.

Christmas, J. Y., G. Gunter, and P. Musgrave
1966. Studies of annual abundance of postlarval penaeid shrimp in the estuarine waters of Mississippi, as related to subsequent commercial catches. Gulf Res. Repts., *2:* 177-212.

Hughes, D. A.
In Press. On the mechanisms underlying tide-associated movements of *Penaeus duorarum*. *In* F.A.O. world scientific conference on the biology and culture of shrimps and prawns, Mexico City, Mexico, June, 1967.

Pearson, J. C.
1939. The early life histories of some American Penaeidae, chiefly the commercial shrimp, *Penaeus setiferus* (Linn.). Bull. U. S. Bur. Fish., No. 30: 1-73.

Renfro, W. C.
1963. Small beam net for sampling postlarval shrimp. Circ. U. S. Bur. Comm. Fish., No. 161: 86-87.

St. Amant, L. S., J. G. Broom, and T. B. Ford
1966. Studies of the brown shrimp, *Penaeus aztecus,* in Barataria Bay, Louisiana. Proc. Gulf & Carib. Fish. Inst., 18th Ann. Sess., 1-17.

Snedecor, G. W.
1956. Statistical methods. 5th Edition. Iowa State College Press, Ames, Iowa, 534 pp.

Tabb, D. C., D. L. Dubrow, and A. E. Jones
1962 Studies of the biology of the pink shrimp, *Penaeus duorarum* Burkenroad, in Everglades National Park, Florida. Tech. Series, Fla. St. Bd. Conserv., No. 37, 32 pp.

Williams, A. B.
1959. Spotted and brown shrimp postlarvae (*Penaeus*) in North Carolina. Bull. Mar. Sci. Gulf & Carib., *9:* 281-290.